Undoped GaAs/AlGaAs Heterostructures

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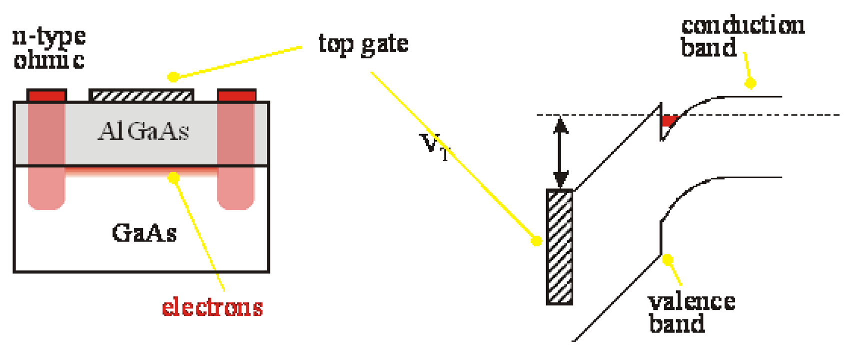
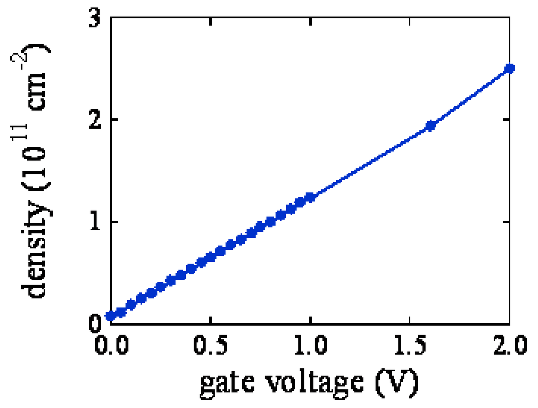
Motivation

- Field-effect transistor device geometry enables variable density 2D systems composed of either electrons or holes
- Very low density 2D electron and hole systems can be achieved.
- The 2D electrons can be very close to the surface, enabling smaller nanoelectronic devices.
- Combined with other fabrication techniques available at Sandia, strongly interacting electron-hole bilayers are possible.

Single Layer 2D Systems

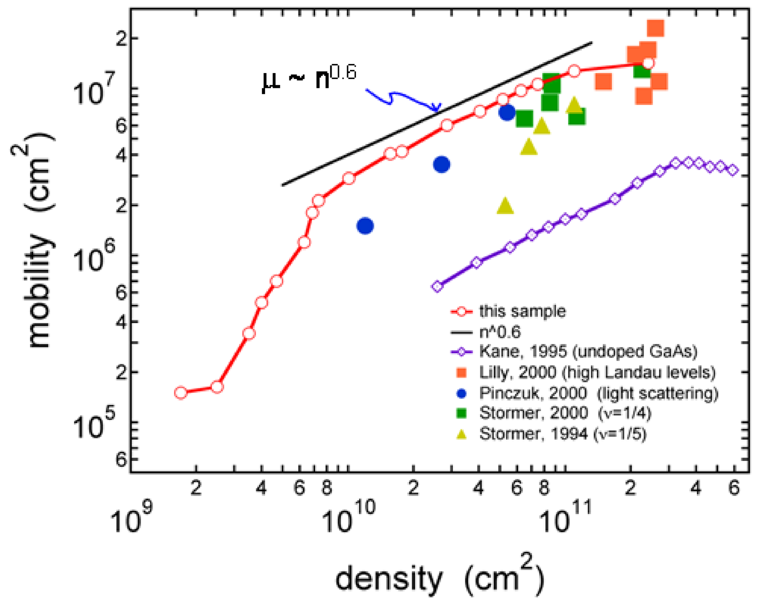
Device Structure and Operation





We have achieved record low 2D electron and hole densities.

Undoped vs. Conventional 2D Electron Systems



- very high mobility at all densities
- peak mobility of 1.3×10^7 cm^2/Vs

Ultra-low Density 2D Electrons

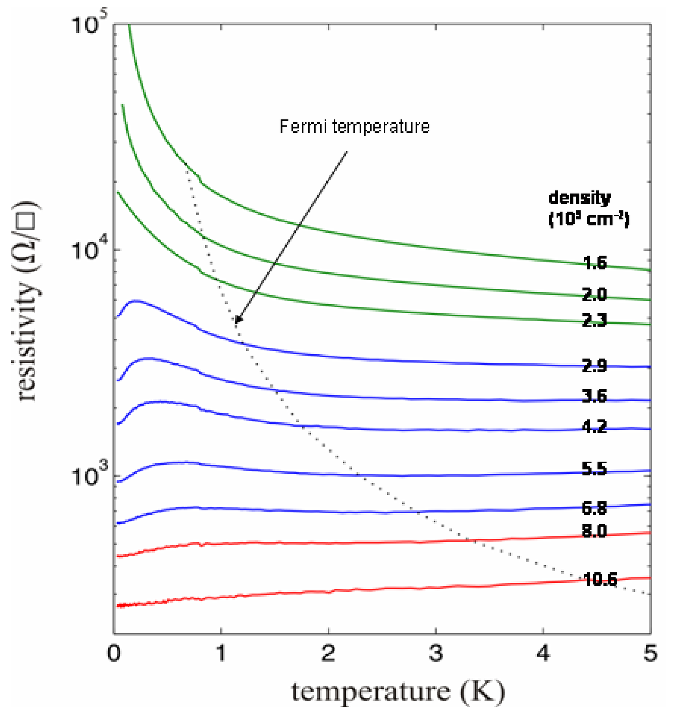
Several low density 2D electron and hole systems exhibit an apparent metal-insulator transition. Since a metallic state at T=0 is unexpected for 2D, it is important to understand in detail the temperature dependence of the resistivity when both Coulomb interactions and disorder are important.

Temperature Dependence of the Resistivity

insulating

non-monotonic

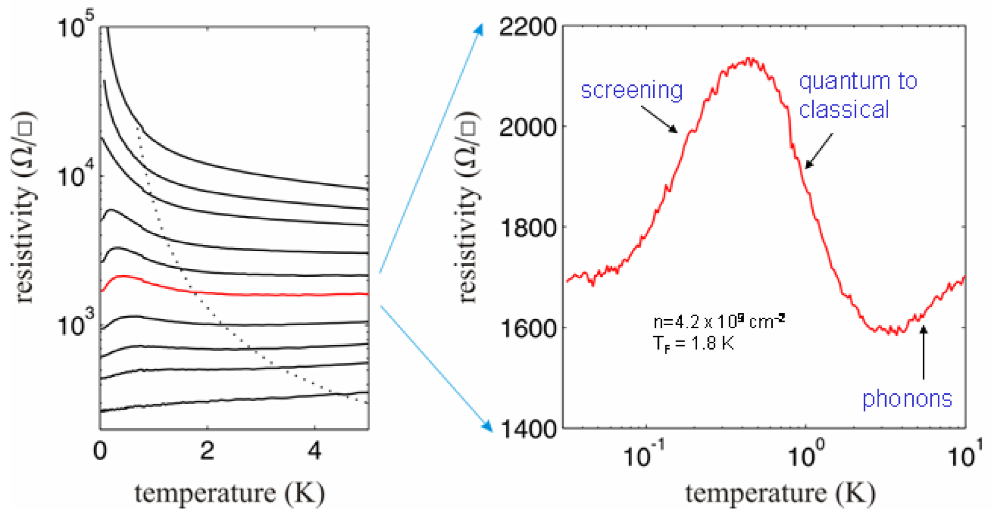
phonon dominated



Scattering mechanisms

1. Remote ionized impurities
2. Phonons
3. ~~Interface roughness~~ small effect for low density
4. ~~Alloy disorder~~ electrons are not in AlGaAs

Non-Monotonic Regime

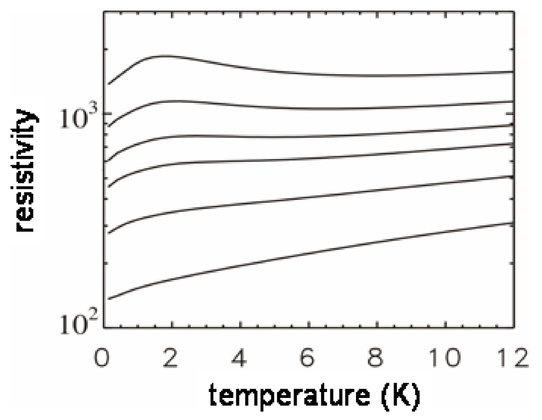


Ionized impurity scattering has temperature dependences for T ~ T_F.

$T \geq T_F$ $\quad r \sim 1/T$ (in limit of classical regime)

$T < T_F$ $\quad r \sim T$ (temperature dependence of screening)

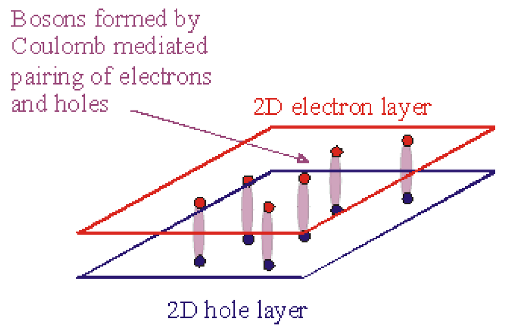
Boltzman scattering calculations



Calculation includes acoustic phonons and ionized impurities. The only adjustable parameters are the bulk and interface impurity density.

The excellent qualitative agreement between theory and experiment suggests that the underlying physics involved is conventional Fermi liquid theory.

Superfluid Transition in Electron-Hole Bilayers

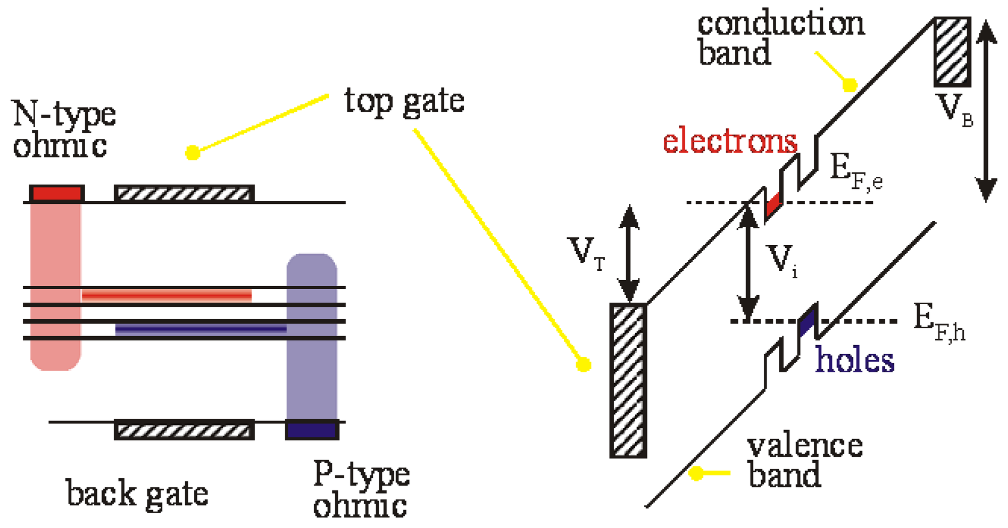


Critical to this experiment:

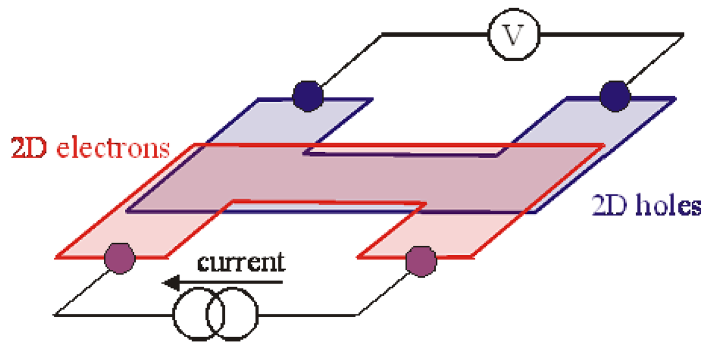
1. low background disorder (high mobility)
2. strong interlayer interactions
   - closely spaced layers
   - low density
3. a measurement technique to detect the superfluid transition (Coulomb drag)

Device Fabrication

- Double quantum wells in undoped GaAs/AlGaAs
- Electrons and holes created using self-aligned contact technique
- Pattern front and back of the sample using EBASE (see Quantum Wire poster)



Coulomb Drag Transport Measurement



If a pairing phase transition occurs, the drag resistivity is expected to diverge

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